GR 1604 B

THE BUNKER-RAMO CORPORATION

[redacted]

METROLOGY LABORATORY

CALIBRATION PROCEDURE

NO. 1559

FOR

GENERAL RADIO, BRIDGE, COMPARISON

MODEL 1604B

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THE BUNKER-RAMO CORPORATION
DEFENSE SYSTEMS DIVISION
8433 FALLBROOK AVENUE • CANOGA PARK CALIFORNIA 91304

METROLOGY LABORATORY CALIBRATION PROCEDURE PROCEDURE NO. 1559

The attached calibration procedure is approved for the calibration of:

General Radio, Comparison Bridge, Model 1604B

REMARKS:

Only the calibration section of this manual is applicable.

APPROVED James E. Pennington

J.E. Pennington, Manager
Metrology Laboratory

OPERATING AND MAINTENANCE INSTRUCTIONS

for

TYPE 1604-B COMPARISON BRIDGE

NO. 113 PROPERTY OF
LABORATORY INSTRUMENT SERVICES
CONTROL SYSTEMS DIVISION
THE RAMO-WOOLDRIDGE CORPORATION

GENERAL RADIO COMPANY

CAMBRIDGE 39 MASSACHUSETTS

NEW YORK CHICAGO WASHINGTON LOS ANGELES

U. S. A.

OPERATING AND MAINTENANCE INSTRUCTIONS

for

TYPE 1604-B COMPARISON BRIDGE

Form 790-B
August, 1954

GENERAL RADIO COMPANY
275 MASSACHUSETTS AVENUE
CAMBRIDGE 39 MASSACHUSETTS

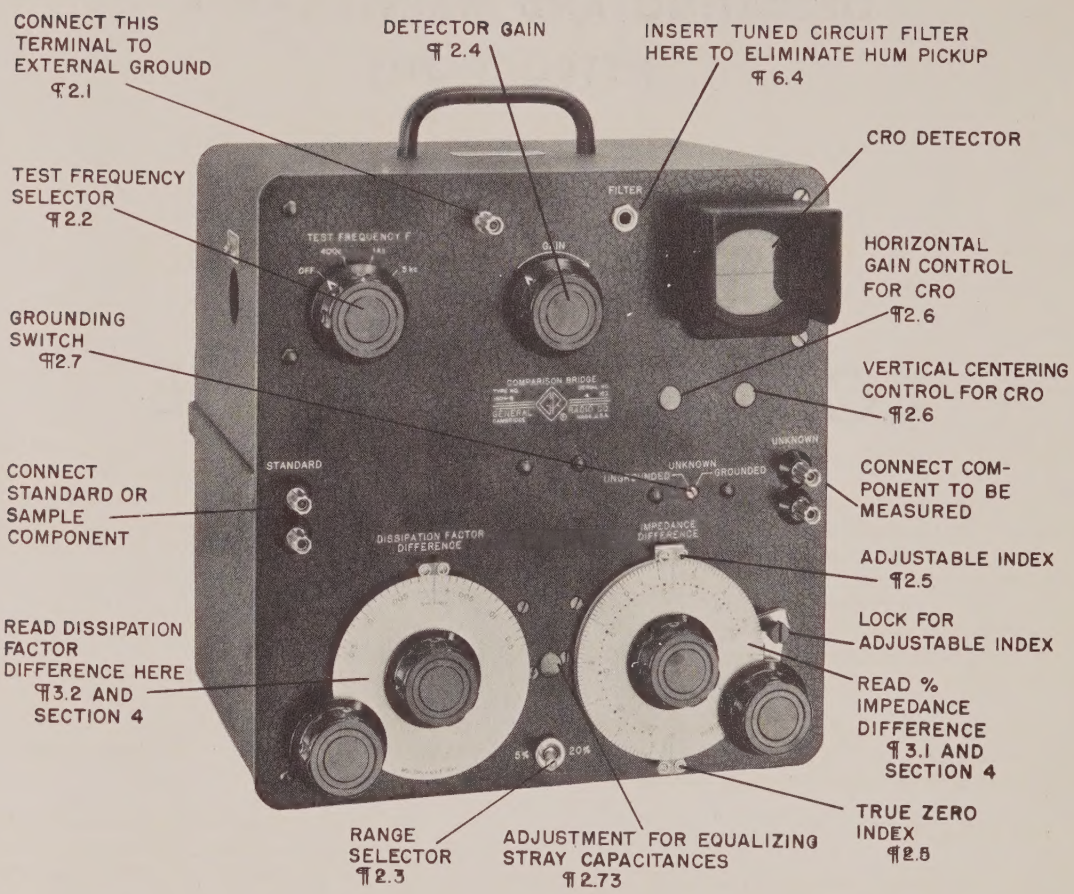
90 West St.
New York 6, N. Y.

920 South Michigan Ave.
Chicago 5, Illinois

8055 13th Street
Silver Spring, Maryland

1000 North Seward St.
Los Angeles 38, Calif.

Printed in U.S.A.


CONNECT THIS TERMINAL TO EXTERNAL GROUND ¶2.1
DETECTOR GAIN ¶2.4
INSERT TUNED CIRCUIT FILTER HERE TO ELIMINATE HUM PICKUP ¶6.4
CRO DETECTOR
TEST FREQUENCY SELECTOR ¶2.2
HORIZONTAL GAIN CONTROL FOR CRO ¶2.6
GROUNDING SWITCH ¶2.7
VERTICAL CENTERING CONTROL FOR CRO ¶2.6
CONNECT STANDARD OR SAMPLE COMPONENT
CONNECT COMPONENT TO BE MEASURED
ADJUSTABLE INDEX ¶2.5
READ DISSIPATION FACTOR DIFFERENCE HERE ¶3.2 AND SECTION 4
LOCK FOR ADJUSTABLE INDEX
READ % IMPEDANCE DIFFERENCE ¶3.1 AND SECTION 4
TRUE ZERO INDEX ¶2.5
RANGE SELECTOR ¶2.3
ADJUSTMENT FOR EQUALIZING STRAY CAPACITANCES ¶2.73
FILTER
STANDARD
UNKNOWN
GROUNDED
DISSIPATION FACTOR DIFFERENCE
IMPEDANCE DIFFERENCE
5%
20%

Panel View of Type 1604-B Comparison Bridge

SPECIFICATIONS

Deviation Range: For impedance difference, ±5% and ±20%, selected by a panel switch. For dissipation factor difference, ±.006 at 400 c, ±.015 at 1 kc, ±.075 at 5 kc.

Impedance Range and Accuracy: Impedances between 2Ω and 20 MΩ can be compared. For the 5% deviation range, the basic accuracy is ±0.1%, but at extreme values of impedance the error is somewhat greater. The range for resistors, capacitors, and inductors for which the ±0.1% accuracy applies is given in the table:

Frequency	*R*	*L*	*C*
400 c	2Ω to 20 MΩ	2 mh to 1500 h	100 μf to 50 μμf
1 kc	2Ω to 20 MΩ	1 mh to 250 h	30 μf to 50 μμf
5 kc	4Ω to 2 MΩ	200 μh to 10 h	2 μf to 50 μμf

These ranges apply for comparison of components whose dissipation factor differences do not exceed .02. On the 20% deviation range, the accuracy is ±0.5% over the same impedance ranges.

Dissipation Factor Accuracy: The accuracy of measurement of differences of dissipation factor is:

Frequency	*Accuracy*
400 c	±(0.0002 + 0.8% of the impedance difference)
1 kc	±(0.0005 + 2% of the impedance difference)
5 kc	±(0.0025 + 10% of the impedance difference)

Frequency: Frequencies of 400 c, 1 kc, and 5 kc are provided, selected by panel switch. The frequency is within ±3% of the nominal value.

Grounding: Two ground positions are provided, one of which grounds the junction of the standard and unknown impedances. With this connection, the total impedances between the high terminals and ground are compared. In the other connection, the junction of the ratio arms of the bridge is grounded, leaving both terminals of the standard and unknown ungrounded. With this connection, the direct impedance between terminals of a component is measured, and terminal impedances to ground, within certain limits, will not affect the bridge balance.

Voltage Applied to Unknown: Approximately one volt, for impedances above 500 Ω. For lower values of impedance the voltage is decreased, corresponding to a source impedance of the order of 100 Ω.

Zero Offset: An adjustable index mark is provided with locking means so that the zero can be offset to correspond to the deviation of the standard component from the desired nominal value.

Power Supply: 105-125 (or 210-250) volts, 50 to 60 cycles.

Accessories Supplied: Line-Connector cord.

Accessories Required: Adjustable calibrated standards such as the TYPE 1432 Decade Resistors, TYPE 219 Decade Capacitors, and TYPE 1490 Decade Inductors may be used. Fixed standards such as the TYPE 509 Standard Capacitors, TYPE 1481 and TYPE 1482 Inductors, and TYPE 500 Resistors may also be used whenever appropriate values are available.

For production tests, the standard is often a component of the type to be tested, that has been measured independently or otherwise selected.

Accessories Available: TYPES 1231-P2 and 1231-P5 Filters for providing frequency discrimination.

Mounting: Welded aluminum cabinet.

Dimensions: (Width) 12 inches, (height) 14¼ inches, (depth) 10 inches, over-all.

Net Weight: 22½ pounds.

OPERATING INSTRUCTIONS

for

TYPE 1604-B COMPARISON BRIDGE

SECTION 1.0 DESCRIPTION

1.1 PRINCIPLE USES

The Type 1604-B Comparison Bridge is a device for measuring the impedance of components rapidly and accurately in terms of percent difference from a standard component or impedance. It is especially useful in production work where resistors, capacitors, or inductors must be adjusted, selected, or paired within a given tolerance. Both the impedance and the dissipation factor of the components are compared.

The bridge is completely self-contained, including generator and detector. Measurements can be made at 400 c, 1 kc, or 5 kc, as selected by a panel switch.

1.2 METHODS OF USE

Two measuring techniques are available: (1) Where the utmost precision of measurement is necessary, the bridge is balanced to a null as indicated on the cathode-ray tube. At balance, the dials indicate directly the impedance difference expressed as a percent of the standard and unknown impedances. (2) For high-speed sorting, the cathode-ray tube can be calibrated and used as an instantaneous go, no-go indication at somewhat reduced accuracy.

1.3 ADDITIONAL USES

In addition to the measurement of simple components, the bridge is very useful in the production testing and adjustment of ganged potentiometers and capacitors for tracking and in checking center-tapped windings for balance.

With suitable adjustable standards, the bridge can be used as a general-purpose laboratory bridge for the precise measurement of resistance, inductance and capacitance.

SECTION 2.0 OPERATION

2.1 GROUNDING AND POWER CONNECTION

The ground terminal provided on the front panel should be connected to a good ground. While most measurements can be made without this connection, a good ground will be most helpful in making high-impedance measurements with the UNKNOWN switch in the UNGROUNDED position.

Connect the bridge to a suitable power source as indicated on the plate over the power receptacle (115 v. or 230 v., 50 - 60 c). Turn the power on by setting the TEST FREQUENCY switch from OFF to the 400 c, 1-kc, or 5-kc position.

2.2 FREQUENCY SELECTION

Measurements may be made at 400 c, 1 kc, or 5 kc by setting the TEST FREQUENCY F switch to the desired frequency. The DISSIPATION FACTOR DIFFERENCE dial is direct reading at 1 kc and its reading must be multiplied by 5 in the 5-kc position, and 0.4 in the 400-c position.

2.3 IMPEDANCE DIFFERENCE RANGE SELECTION

Two impedance difference ranges are provided: one, 0 to $\pm 5\%$ for accurate comparison of precision compoents; the other 0 to $\pm 20\%$ for checking to the common commercial tolerances of $\pm 10\%$ and $\pm 20\%$. These ranges are selected by the toggle switch at the bottom of the front panel.

2.4 GAIN CONTROL

Set the GAIN control at about the middle of its range Generally, a position can be selected so that a readjustment of the GAIN control is unnecessary as the bridge balance is approached. Setting the gain too high initially will make the balance point difficult to find.

2.5 OFFSET ZERO

The true zero of the IMPEDANCE DIFFERENCE dial is indicated by the index line engraved under the word PERCENT and the indicator at the bottom of the dial. A second indicator is provided at the top of the dial which

can be moved by releasing the locking knob at the right of the dial. This permits off-setting the indicated zero to allow for error in the standard. For example, if the impedance of an available standard is 0.8% higher than the desired nominal value, move the adjustable indicator 0.8% clockwise. The dial indication is now the deviation from the desired nominal value. When the zero is offset, there is introduced an error equal to the product of the offset and the indicated impedance difference. Thus, with an offset of 2% and an impedance difference of 5%, the error is 0.1%.

2.6 CATHODE-RAY TUBE CONTROLS

2.61 A vertical centering control is provided under the right-hand snap button immediately below the cathode-ray tube.

2.62 A horizontal gain control for the oscilloscope tube is located under the left-hand snap button immediately below the tube. This may be set for any desired horizontal deflection. Under conditions of high ambient lighting, reducing the horizontal deflection will increase the intensity of the trace and make the balance point easier to see.

The projecting light shield can be slid off the tube bezel if not required, and may be slid on in different directions to give maximum protection from external light.

2.7 UNKNOWN GROUNDED - UNGROUNDED SWITCH

2.71 UNKNOWN GROUNDED: For this connection the lower terminals of the STANDARD and UNKNOWN are grounded so that the impedances being compared are the total impedances from the high STANDARD and UNKNOWN terminals to ground. Thus the capacitance and leakage to ground from the high terminals of the standard and unknown being compared are included in the measurement. In addition, there is stray circuit capacitance of approximately 40 $\mu\mu$f across each pair of terminals. These shunt impedances, although unimportant when comparing low values of impedance, will cause errors at high-impedance levels. For this reason, high values of impedance should be compared in the UNGROUNDED connection for which the capacitance across the terminals is only about 0.8 $\mu\mu$f. See also Paragraph 2.73. If for any reason high-impedance components must be measured with one terminal grounded, the error in the IMPEDANCE DIFFERENCE dial introduced by the 40 $\mu\mu$f can be estimated with reasonable accuracy (see Paragraph 4.31).

2.72 UNKNOWN UNGROUNDED: When the switch is in this position, the junction of the bridge ratio arms is grounded leaving both terminals of the STANDARD and UNKNOWN ungrounded (see Figure 1). Thus the direct impedances between terminals of the components are compared. Impedance from the lower STANDARD or UNKNOWN terminals to ground will appear across the detector input and will not affect the bridge balance point. Impedance from the upper STANDARD or UNKNOWN terminals to ground appears across the resistive ratio arms and, therefore, must be as high as possible compared to the 25 KΩ ratio arms. Reasonable leakage and shunt capacitance can be tolerated across these ratio arms.

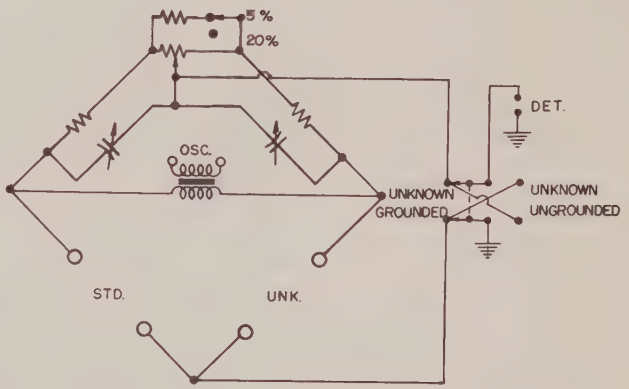


Figure 1

2.73 The adjustable capacitor (C-16), accessible under the snap-button between the dials, is provided for equalizing the capacitance across the bridge arms. The correct setting of this capacitor is different for the two positions of the UNKNOWN-UNGROUNDED-GROUNDED switch because of the slightly different stray capacitances in the two cases. To adjust this capacitor properly, set the IMPEDANCE DIFFERENCE dial to zero and balance the bridge with C-16 and the DISSIPATION FACTOR DIFFERENCE dial. This adjustment should be made with the UNKNOWN and STANDARD terminals open. This adjustment may also be made with leads attached to compensate for small differences in lead capacitance.

2.8 BALANCE PROCEDURE

Connect the standard and unknown impedances to the corresponding terminals of the bridge. Adjust the IMPEDANCE DIFFERENCE and DISSIPATION FACTOR DIFFERENCE dials until the band of light on the oscilloscope is of minimum height. At this balance point, the right-hand dial indicates directly the impedance difference expressed as a percent of the standard impedance. The left-hand dial indicates the difference of the dissipation factors.

2.9 GO, NO-GO SORTING PROCEDURE

The Type 1604-B Comparison Bridge can be used as a visual "go, no-go" device to sort components to any desired tolerance. In this use, no balancing operation is necessary. The cathode-ray tube is calibrated to give an instantaneous indication.

In this application, the bridge measures the magnitude of the bridge unbalance voltage and gives no information about the phase of this voltage. Thus, no distinction is made between dissipation factor error and impedance difference error.

2.91 Preliminary Set-Up: 5% range

2.911 Connect the "standard" to the STANDARD terminals.

2.912 Connect one of the components to be sorted to the UNKNOWN terminals and balance the bridge in the usual manner (see Paragraph 2.8).

2.913 Release the top impedance-difference-dial indicator by rotating the thumb screw lock at the right of the dial. With the bridge still balanced, leave the impedance difference dial set and rotate the indicator to the zero of the impedance difference dial.

2.914 Displace the IMPEDANCE DIFFERENCE dial from this balance position by the desired sorting tolerance.

2.915 Turn the vertical centering control (see Paragraph 2.61) completely counter-clockwise.

2.916 Adjust the GAIN control so that the top of the band of light is on the indicator line.

2.917 Set the DISSIPATION FACTOR DIFFERENCE dial to zero.

2.918 Return the IMPEDANCE DIFFERENCE dial to its true zero, (indicator at bottom of dial), or to its offset zero (see Paragraph 2.5). The bridge is now set up for a sorting operation. Connect one of the components to be sorted to the UNKNOWN terminals. If the resulting band of light on the oscilloscope extends above the indicator line, the component is outside the desired tolerance either in impedance or dissipation factor. If the band of light is below the indicator line, the component is within tolerance.

2.92 Preliminary Set-Up: 20% range

Since the bridge unbalance voltage is slightly different for equal positive and negative sorting tolerances, the gain control can be set correctly for either a positive or negative sorting tolerance, but not both. While this effect is negligible on the 5% range, it is important on the 20% range, and the zero should be offset to allow for this as follows:

2.921 Connect the "standard" to the STANDARD terminals.

2.922 Connect one of the components to be sorted to the UNKNOWN terminals and balance the bridge in the usual manner. For maximum accuracy, use an unknown that is as close as possible to the standard (at least within 5%).

2.923 With the bridge balanced, leave the impedance-difference dial set and move the adjustable indicator at the top of the dial so that it indicates $\frac{(-T^2)}{2}$ where T is the desired sorting tolerance. For example, if T is $\pm 20\%$, set the indicator to $\frac{-(0.2)^2}{2} = -.02 = -2\%$. Now with the indicator set, rotate the impedance-difference dial so that it indicates (-T); (-20% in example).

2.924 Turn the vertical centering control (see Paraph 2.61) completely counter-clockwise.

2.925 Adjust GAIN control so that the top of the band of light on the oscilloscope is on the indicator line.

2.926 Set the DISSIPATION FACTOR DIFFERENCE dial to zero.

2.927 Return the IMPEDANCE DIFFERENCE dial to its true zero (indicator at bottom of dial). Set the adjustable indicator to zero, or to its offset zero (see Paragraph 2.5). Rotate the IMPEDANCE DIFFERENCE dial to $(-T^2/2)$. The bridge is now set up for a sorting operation. Connect one of the components to be sorted to the UNKNOWN terminals. If the resulting band of light on the oscilloscope extends above the indicator line, the component is outside the desired tolerance either in impedance or dissipation factor. If the band of light is below the indicator line, the component is within tolerance.

2.93 Preliminary Set-Up: 20% range for unequal positive and negative sorting tolerances.

Occasionally it may be necessary to sort components with unequal positive and negative tolerances, for example, +40%, -15%. The zero can be offset to permit this. The amount and direction of the offset is given by:

$$\alpha = 2\left(\frac{A + B + AB}{4 + A + B}\right)$$

where:

A = the upper sorting tolerance
B = the lower sorting tolerance
α = the zero offset

For example:

A = +40% = +0.40
B = -15% = -0.15

$$\alpha = 2\left(\frac{0.40 - 0.15 - 0.06}{4.00 + 0.40 - 0.15}\right) = +0.0894 = +8.94\%$$

2.931 Set the adjustable indicator to its true zero or offset zero position (see Paragraph 2.5).

2.932 Rotate the IMPEDANCE DIFFERENCE dial to α.

2.933 Connect the standard to the standard terminals.

2.934 Connect a component to the unknown terminals that is known to be at the upper or lower sorting tolerance. (A decade box is most convenient for this purpose.)

2.935 Turn the vertical centering control (see Paragraph 2.61) completely counter-clockwise.

2.936 Adjust the GAIN control so that the top of the band of light is on the indicator line. The bridge is now set up for a sorting operation. Connect one of the components to be sorted to the UNKNOWN terminals. If the resulting band of light on the oscilloscope extends above the indicator line, the component is outside the desired tolerance either in impedance or dissipation factor. If the band of light is below the indicator line, the component is within tolerance.

SECTION 3.0 DIAL CALIBRATIONS

3.1 IMPEDANCE DIFFERENCE DIAL

This dial reads the magnitude of the impedance of the unknown minus the magnitude of the impedance of the standard expressed as a percent of the impedance of the standard:

$$\frac{|Z_X| - |Z_N|}{|Z_N|} \times 100 \ (\%)$$

For components that are nearly pure R, L, or C, the bridge indicates:

3.11 Resistors:

$$\frac{R_X - R_N}{R_N} \times 100 \ (\%)$$

3.12 Inductors:

$$\frac{L_X - L_N}{L_N} \times 100 \ (\%)$$

3.13 Capacitors:

$$\frac{\frac{1}{C_X} - \frac{1}{C_N}}{\frac{1}{C_N}} = \frac{-(C_X - C_N)}{C_X} \times 100 \ (\%)$$

NOTE

In checking capacitors, it is sometimes inconvenient to have the bridge indicate impedance difference. However, if the positions of the unknown and the standard are interchanged, this expression becomes:

$$\frac{C_X - C_N}{C_N} \times 100 \ (\%)$$

The dial then indicates capacitance difference rather than impedance difference.

3.2 DISSIPATION FACTOR DIFFERENCE DIAL

When capacitors or inductors are compared, this dial indicates the dissipation factor of the component connected to the unknown terminal minus the dissipation factor of the component connected to the standard terminal ($D_X - D_n$). When resistors are compared, the dial indicates $-(Q_X - Q_n)$, where Q and D are defined as below.

3.21 Capacitors:

$D = R_S \omega C$

$D = \frac{1}{R_P \omega C}$

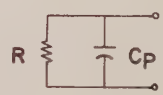
3.22 Inductors:

$D = -\frac{R_S}{\omega L}$

$D = -\frac{\omega L}{R_P}$

3.23 Resistors:

$Q = -\frac{\omega L_S}{R}$



$Q = +R\omega C_P$

For D less than 0.25, the DISSIPATION FACTOR DIFFERENCE dial indicates phase angle difference in radians. This can be converted to a phase angle in degrees by multiplying the dial reading by 57.3.

SECTION 4.0 RANGE AND ACCURACY

4.1 IMPEDANCE RANGE AND ACCURACY

Impedances between 2Ω and 20 MΩ can be compared. For the 5% deviation range, the basic accuracy is ±0.1%, but at extreme values of impedance, the error is somewhat greater. The range for resistors, capacitors, and inductors for which the ±0.1% accuracy applies is given in the table:

Freq.	R	L	C
400 c	2Ω to 20 MΩ	2 mh to 1500 h	100 μf to 50 μμf
1 kc	2Ω to 20 MΩ	1 mh to 250 h	30 μf to 50 μμf
5 kc	4Ω to 2 MΩ	200 μh to 10 h	2 μf to 50 μμf

On the 20% deviation range, the accuracy is ±0.5% over the same impedance ranges.

The full accuracy of impedance-difference measurements is realized over these ranges provided the dissipation factors of the components being compared differ by less than ±.02. This .02 limit on dissipation-factor difference is only about one-fourth full scale on the dial at 5 kc and is indicated by the red engraving for convenience.

4.2 DEVIATION RANGE

Two impedance-difference ranges are provided: one, 0 to ±5% for accurate comparison of components close to each other in value; the other, 0 to ±20%, of somewhat lesser accuracy, for checking to the common commercial tolerances of ±10% and ±20%.

The dissipation-factor-difference range is ±0.006 at 400 cycles, ±0.015 at 1 kc, and ±0.075 at 5 kc. The full accuracy of impedance-difference measurements is realized only when the components being compared differ in dissipation factor by less than ±.02.

4.3 ACCURACY

The accuracy of the bridge is limited by three factors which become important only at the extreme values of impedance or for large impedance differences between components.

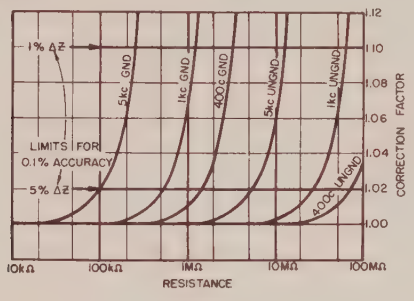


Figure 2

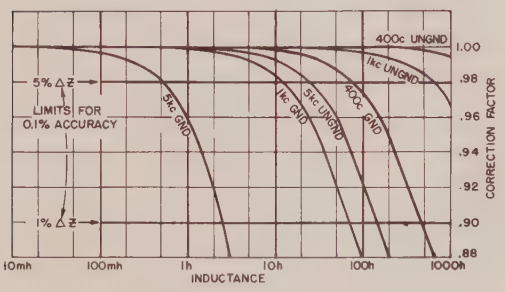


Figure 3

4.31 High-Impedance Limit: The bridge measures the total impedance across its terminals including all stray impedances as well as the components under test. This will cause an apparent error in the IMPEDANCE DIFFERENCE dial as shown in Figures 2, 3, 4. The correction factor plotted is the factor by which the IMPEDANCE DIFFERENCE dial reading must be multiplied to get the actual impedance difference. For an impedance difference of 5.0%, the error will not reach 0.1% until this factor reaches 1.02 (since 1.02 x 5.0% = 5.1%). The UNKNOWN switch is provided to minimize this error (see Paragraph 2.7).

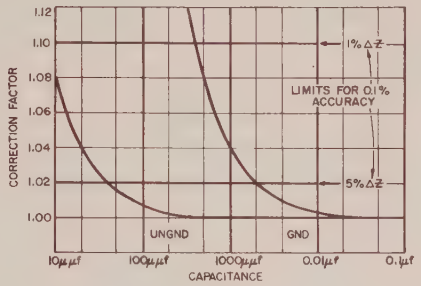


Figure 4

Above 20 megohms the bridge sensitivity is not sufficient to balance to an accuracy of 0.1%. The high-impedance range, therefore, is limited by Figures 2, 3 and 4 or 20 megohms, whichever is the lesser.

4.32 Low-Impedance Limit: At low impedance, decreased sensitivity and small unbalance in the impedances in series with the STANDARD and UNKNOWN terminals combine to limit the accuracy. The series impedance unbalance tends to move the true bridge zero as is shown in Figures 5, 6, and 7 for R, L, and C, respectively. These curves represent the worst conditions, individual instruments varying from zero error to this maximum error. If measurements are to be made with maximum accuracy at the extreme low-impedance limit, the bridge zero can be offset to take care of these small bridge errors. The errors can be determined accurately at a given impedance level by making an impedance-difference measurement, ΔZ_1 (%), in the normal manner with two components which are within 1% of each other, and then making a second measurement, ΔZ_2 (%), with the standard and unknown reversed. The true bridge zero is then

$$\frac{\Delta Z_1 + \Delta Z_2}{2}$$

For example, if ΔZ_1 were +0.9% and ΔZ_2 were -0.7%, then the true bridge zero would be at

$$\frac{+0.9\% + (-0.7\%)}{2} = +0.1\%$$

If the bridge zero is offset +0.1% and the measurement repeated, $\Delta Z_1 = -\Delta Z_2 = +0.8\%$.

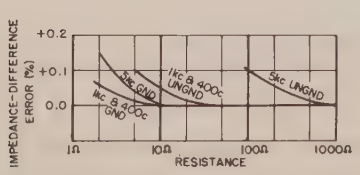


Figure 5

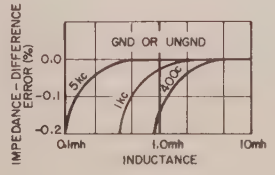


Figure 6

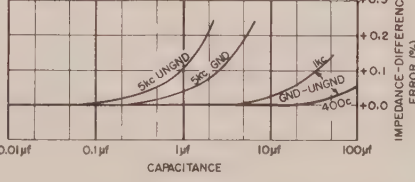


Figure 7

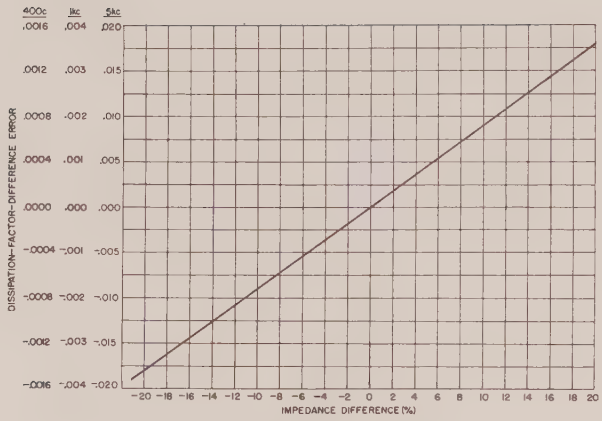


Figure 8

4.33 Cross Coupling Effects: The indication of the DISSIPATION FACTOR DIFFERENCE dial depends to a small extent on the indication of the IMPEDANCE DIFFERENCE dial. This dependency is shown in Figure 8 and limits the accuracy of the DISSIPATION FACTOR DIFFERENCE dial. At 5 kc, additional errors appear on both the IMPEDANCE DIFFERENCE dial and the DISSIPATION FACTOR DIFFERENCE dial. These errors are shown in Figures 9 and 10 and limit the bridge to dissipation-factor differences of 0.02 at 5 kc for an IMPEDANCE DIFFERENCE dial accuracy of 0.1%.

4.34 Cathode-Ray Tube Calibration: When the instrument is used as a visual "go, no-go" device to sort components, there can be an additional error in the calibration of the cathode-ray tube which may be as large as 5% of the sorting tolerance. This is normally not too important since even for ±5% tolerances, the error will be less than ±0.25% (±0.05 x 0.05 = ±0.25%).

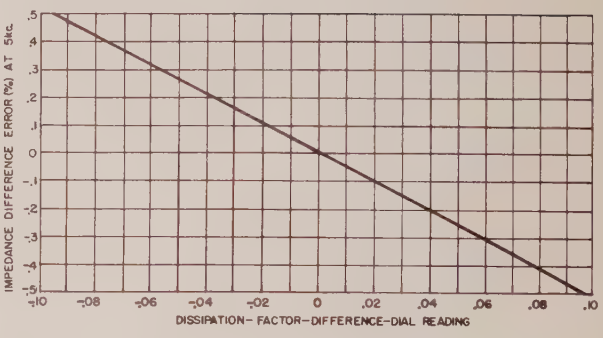


Figure 9

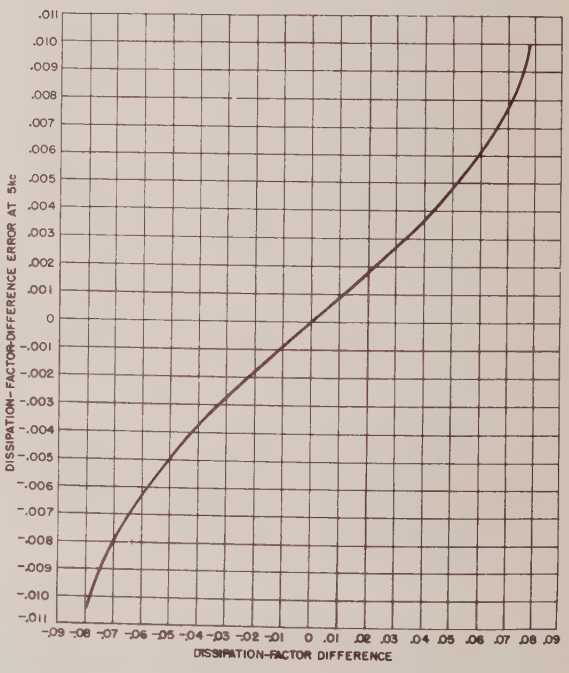


Figure 10

SECTION 5.0 SPECIAL MEASUREMENTS

5.1 MEASUREMENTS OF SMALL CAPACITORS

Capacitors from 0.1 μμf to 20 μμf can be measured directly and conveniently without the use of small standard capacitors.

5.11 Preliminary Set-Up:

5.111 Place the UNKNOWN GROUNDED - UNGROUNDED switch in the UNGROUNDED position.

5.112 Place range switch at 5%.

5.113 Connect two capacitors 100 μμf ±2% across the STANDARD and UNKNOWN terminals.

5.114 Balance the bridge in the normal manner.

5.115 Set the offset zero indicator so that the dial indicates zero.

5.12 Procedure:

5.121 Add the unknown capacitor to be measured in parallel with the 100 μμf capacitor on the STANDARD terminals.

5.122 Balance the bridge in the normal manner.

5.13 Range: The IMPEDANCE DIFFERENCE dial is now direct-reading in μμf added to the 100 μμf capa-

citor, the full-scale range being ±5 μμf (±5% of 100 μμf). When different shunting capacitors are used, the full scale reading can be varied, the bridge always reading ±5% of the shunting capacitor. In the same way, the bridge can be set up on the ±20% range to cover a larger range with reduced accuracy.

5.2 COMPARISON OF TURNS RATIO

Transformers can be checked easily for proper turns ratio, or windings checked for accurate center tapping. For checking center taps or unity turns ratio of windings with reasonable Q, the windings may be connected to the STANDARD and UNKNOWN terminals of the bridge as in Paragraph 5.21 (Method I) and the unbalance read directly. Full bridge accuracy will be obtained provided there is sufficient coupling between the windings, and the windings are reasonably similar in resistance and stray capacitance. For comparing low Q windings or windings with odd turns ratios on different cores, the connection described in Paragraph 5.23 (Method II) should be used.

5.21 Preliminary Set-Up: Method I

5.211 To check a center-tapped winding, connect one end of the winding to the upper STANDARD terminal, the other end to the upper UNKNOWN terminal, and the center tap to the lower terminal on either the standard or unknown side of the bridge (these lower terminals are common).

5.212 To check two windings for unity turns ratio, connect them in series aiding and then connect them to the bridge as a center-tapped winding (Paragraph 5.211).

5.22 Procedure: Method I

5.221 Balance the bridge in the normal manner.

5.222 The impedance-difference dial indicates the percent unbalance in the two windings. For windings of reasonable Q, this is:

$$\frac{N_x - N_n}{N_n} \times 100 \ (\%)$$

where N_x and N_n are the numbers of turns in the windings connected to the unknown and standard arms of the bridge, respectively.

Since the bridge measures impedance difference rather than turns-ratio difference, the bridge measurement for windings of low Q will be in error by the factor $\sqrt{1 + D^2}$. For D less than 0.2 (Q>5), this factor is less than 1.02 and can be neglected.

5.23 Preliminary Set-Up: Method II

5.231 Place the UNKNOWN switch in the ungrounded position.

5.232 Obtain two resistors within 2% of the same value (1000 ohms is suitable). Connect them in series between the upper STANDARD and UNKNOWN terminals as shown in Figure 11.

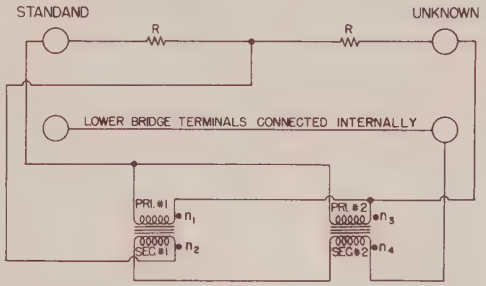


Figure 11

5.233 Connect a jumper from the center tap of the two series resistors to the lower UNKNOWN terminal. Balance the bridge in the normal manner and set the adjustable indicator to zero. Remove the jumper.

5.24 Procedure: Method II

5.241 To check the turns ratios of two transformers, connect the primaries in parallel across the bridge generator, and the secondaries in series opposing to the bridge detector as is shown in Figure 11.

5.242 Balance the bridge in the normal manner. The impedance-difference dial indicates:

$$4 \left(\frac{N_2}{N_1} - \frac{N_4}{N_3} \right) \times 100 \ (\%)$$

5.243 To check two secondary windings on a single core for unity turns ratio, use a single primary in place of the two in parallel and connect as in Figure 11. The impedance-difference dial indicates:

$$4 \left(\frac{N_{sec_1} - N_{sec_2}}{N_{pri}} \right) \times 100 \ (\%)$$

5.3 MEASUREMENTS WITH A POLARIZING VOLTAGE

A d-c polarizing voltage (400 volts maximum) can be applied to components under test. This voltage is applied to both the standard and unknown and must be applied through a series resistor to maintain sufficient bridge sensitivity. This resistor should be greater than 0.1 of the impedance of the standard component at the frequency of the measurement but in no case less than 2 kΩ. When capacitors are being measured, the full applied voltage will appear across the capacitors. For resistors, however, a voltage division occurs and a d-c vacuum-tube voltmeter will be necessary across the unknown resistor to measure the actual applied voltage.

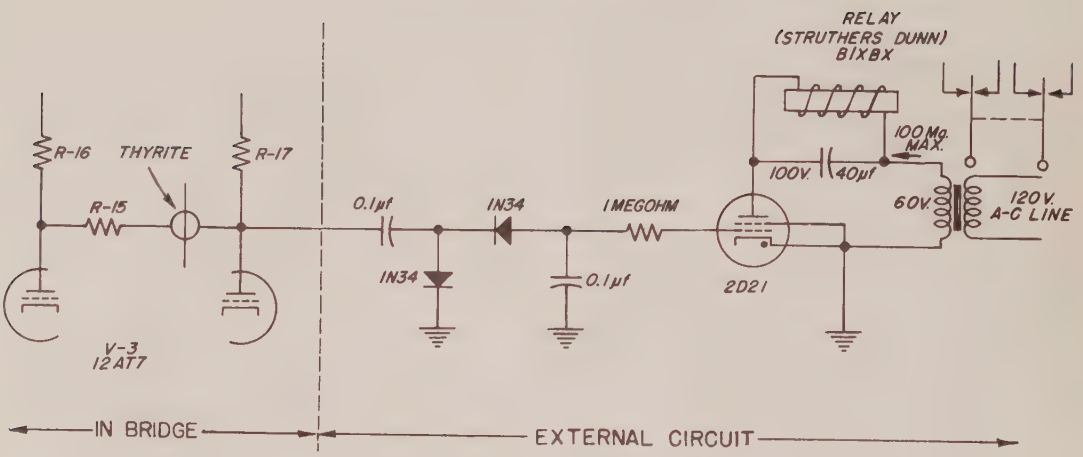


Figure 12

Measurements may be made with the UNKNOWN switch in either GROUNDED or UNGROUNDED position. With the unknown ungrounded, some shielding may be necessary to reduce hum pickup, although the use of a filter will usually suffice. With the unknown grounded, an additional lead must be brought out from the bridge.

5.31 UNKNOWN UNGROUNDED: Connect one side of a battery to the available ground binding post and the other through a suitable resistor to the lower STANDARD or UNKNOWN bridge terminal (these terminals are common).

5.32 UNKNOWN GROUNDED: In this switch position, the lower STANDARD and UNKNOWN (common) terminals are grounded. Thus, one terminal of the battery may be connected to ground. However, the other battery terminal must be connected through a suitable resistor to the opposite bridge diagonal (the detector input). This can be done by bringing out a shielded lead from C-18 (mounted on the UNKNOWN switch) making sure that C-18 still serves to block any dc from the grid of V-1 (see Wiring Diagram, page 12).

5.4 AUTOMATIC SORTING

The large error signal available at the plates of the cathode-ray indicator can be used in many ways to operate automatic equipment limited only by the ingenuity of the designer.

One of the simplest methods to operate automatic equipment is shown in Figure 12. In this circuit, the error voltage is rectified and used to bias a thyratron to cut-off. If the unknown component is within tolerance, the bias will be reduced to the point where the thyratron will operate the relay. Sufficient sensitivity is available to select components with 0.02 percent of the desired value. The gain control on the bridge can be used to decrease this sensitivity to sort to any tolerance. A simple circuit like this operates on the magnitude of the error signal and will reject components if either the impedance or dissipation factor is outside the limit set.

SECTION 6.0 ELECTRICAL CIRCUITS

6.1 GENERAL

The Type 1604-A Comparison Bridge is completely self-contained, consisting of an oscillator, bridge, visual detector, and associated power supplies.

6.2 BRIDGE

The bridge circuit is shown in Figure 10. The impedance difference is balanced by the resistive divider in the ratio arms, and the dissipation-factor difference by a differential capacitor across these arms. A switch (5% - 20%) is provided to decrease the range of the impedance-difference potentiometer from 20% to 5% by shunting the potentiometer with a fixed resistor.

6.3 OSCILLATOR

The oscillator is a resistance-capacitance oscillator (see Figure 13). The phase-shift capacitors are switched (TEST FREQUENCY F switch) when frequency is changed so that the impedance is the same at all frequencies. Limiting is obtained by using a non-linear resistor (Thyrite) in the plate circuit of the oscillator. A cathode follower is used to couple the oscillator to the bridge input transformer. Capacitive coupling through

the bridge transformer is eliminated by careful shielding of both primary and secondary windings. Any unbalance of the capacitance from each half of the secondary winding to its shield is corrected with differential capacitor C-16.

6.4 DETECTOR

A high-gain, three-stage amplifier is used to supply a push-pull error voltage to the vertical deflection plates of the cathode-ray-tube indicator. A FILTER jack is provided at the grid of the second stage for the insertion of a 400 c, 1-kc or 5-kc filter of the parallel-resonant-circuit type, such as the Type 1231-P2 or 1231-P5. While this filter is not necessary, it will provide a somewhat cleaner null especially when measuring high impedances in the presence of stray fields.

A Thyrite limiter is connected between the push-pull plates of the third amplifier stage to decrease the gain for large error voltages. The gain is automatically increased as the null is approached, thus permitting rapid balancing of the bridge.

6.5 SWEEP

A free-running multivibrator is used to provide a high-frequency push-pull sweep. The resulting band of light provides a convenient and simple off-balance indication.

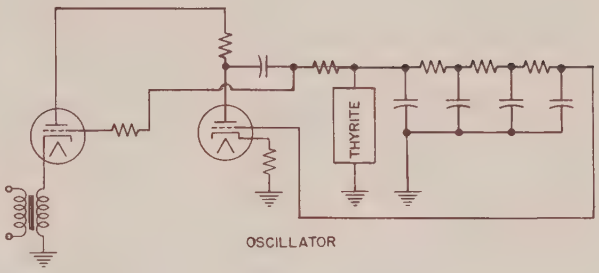


Figure 13

6.6 POWER SUPPLIES

A half-wave rectifier is used to supply +270 volts to the oscillator, amplifier, and the second anode of the CRO. A conventional resistance-capacitance filter is used. An additional half-wave rectifier is used to supply -300 volts to the cathode of the cathode-ray-oscilloscope.

SERVICE AND MAINTENANCE NOTES

This service information, together with the information given in the Operating Instructions, should enable the user to locate and correct ordinary difficulties resulting from normal use.

Major service problems should be referred to our Service Department which will cooperate as far as possible by furnishing information and instructions as well as supplying any replacement parts required.

When contacting our Service Department regarding any difficulties in operation or service of the instrument the serial number as well as the type number of the instrument should always be mentioned. A complete report of the troubles encountered, with specific reference to the numbered paragraphs in the Operating Instructions and the Service Information pertaining to these particular troubles, as well as any further information concerning the use of the instrument and steps taken to eliminate the difficulties, should also be included in any correspondence.

Please write to our Service Department for a Returned Material Tag, which includes shipping instructions, to insure proper handling and identification before returning any instrument or parts for repair. A purchase order covering material returned for repair should also be forwarded to avoid any unnecessary delay.

1.0 LACK OF SENSITIVITY

1.1 Low oscillator voltage will lower the sensitivity of balance appreciably, particularly when low impedances are being compared.
1.2 When a 1000-ohms-per-volt a-c meter is used, the voltage between the upper STANDARD and UNKNOWN terminals should be greater than 1.5 volts.
1.3 Replace the oscillator tube V-4 to satisfy this condition.

2.0 LACK OF DEFINITION ON CATHODE-RAY TUBE

2.1 When V-7 has been replaced or after V-7 has operated for a long period of time, the line visible on its screen at balance may become thicker and lack sharpness.
2.2 Set the GAIN control fully counterclockwise and adjust the focus control R-46, located on the chassis to the left of the base of V-7, for minimum thickness of the line.

3.0 NO HORIZONTAL DEFLECTION ON SCREEN OF V-7.

3.1 Replace horizontal sweep tube, V-5.
3.2 Check voltages for V-5 per table in Paragraph 6.1 if replacement tube does not restore operation.

4.0 NO VERTICAL DEFLECTION ON SCREEN OF V-7

4.1 Refer to Paragraph 1.0 above.

4.2 Check or replace vertical amplifier tubes V-1, V-2, and V-3.
4.3 Refer to voltage table in Paragraph 6.1 for V-1, V-2, and V-3 if replacements do not restore operation.

5.0 SCREEN OF V-7 COMPLETELY DARK

5.1 Replace rectifier tube V-6.
5.2 Refer to voltage table in Paragraph 6.1 for V-6 and V-7.
5.3 Replace V-7 if replacement of V-6 does not restore operation and voltages at V-6 and V-7 are normal.

6.0 TUBE VOLTAGES

6.1 Conditions of Measurements:

Line Voltage - 115 volts

D-C voltages are measured with a 20,000-ohms-per-volt d-c meter connected between the tube socket terminal and the chassis (ground) except where noted below.*

A-C voltages are measured with a 1,000-ohms-per-volt a-c meter connected between the tube socket terminal and the chassis (ground) except for V-6 and V-7 where connections are made between the terminals indicated by the "H" as noted below.

All readings are subject to 20% variation.

Power Input - 30 watts

7.0 TRANSFORMER T-2 RESISTANCE

Primary - 1200 ohms
Secondary - 55 ohms

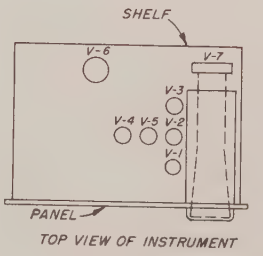
Tube	Type	Tube Socket Terminal Number											
		1	2	3	4	5	6	7	8	9	10	11	12
V-1	6AU6	0	0	0	6.4 a.c.	24	25	0					
V-2	6AU6	0	0.8	0	6.4 a.c.	155	32	0.8					
V-3	12AT7	144	45 - 72	72	6.4 a.c.	6.4 a.c.	144	60**	72	0			
V-4	12AT7	275	0	5.0	6.4 a.c.	6.4 a.c.	144	0	1.8	0			
V-5	12AT7	70	-1.4	0	6.4 a.c.	6.4 a.c.	70	-1.4	0	0			
V-6	117Z6-GT		H	285 a.c.	340	-290	—	H	285 a.c.				
V-7	2BP1	H	3.5*	—	85*		144	144	440*	70	70		H

*Negative side of meter connected to terminal 2 of V-7.

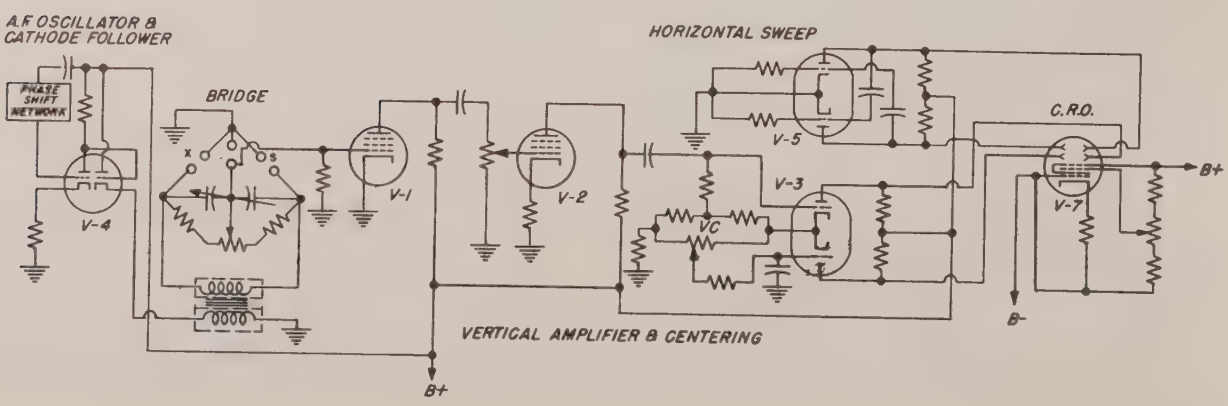
**Measure with a V.T.V.M.

H - 6.4 volts a-c for V-7 and 90 volts a-c for V-6 between indicated terminals.

Tube Layout



Schematic Wiring Diagram for Type 1604-B Comparison Bridge



Parts List for the Type 1604-B Comparison Bridge

RESISTORS

R-1	=	4.7 Megohms	±10%	REC-20BF
R-2	=	470 kilohms	±10%	REC-20BF
R-3	=	220 kilohms	±10%	REC-20BF
R-4	=	0.5 Megohms	±10%	POSC-12
R-5	=	1 kilohm	±10%	REC-20BF
R-6	=	470 kilohms	±10%	REC-20BF
R-7	=	100 kilohms	±10%	REC-20BF
R-8	=	1 Megohm	±10%	REC-20BF
R-9	=	1200 Ohms	±10%	REC-20BF
R-10	=	1200 Ohms	±10%	REC-20BF
R-11	=	50 kilohms	±10%	POSC-11
R-12				
R-13	=	27 kilohms	±10%	REC-20BF
R-14	=	Thyrite		REU-8
R-15	=	10 kilohms	±10%	REC-20BF*
R-16	=	100 kilohms	±10%	REC-20BF
R-17	=	100 kilohms	±10%	REC-20BF
R-18	=	100 Ohms	±10%	REC-20BF
R-19	=	33 kilohms	± 5%	REC-20BF
R-20	=	470 Ohms	± 5%	REC-20BF
R-21	=	22 kilohms	± .1%	REF-2
R-22	=	39 kilohms	± 1%	REF-2
R-23	=	39 kilohms	± 1%	REF-2
R-24	=	39 kilohms	± 1%	REF-2
R-25	=	Thyrite		REU-8
R-26	=	470 kilohms	±10%	REC-20BF
R-27	=	470 kilohms	±10%	REC-20BF
R-28	=			
R-29				
R-30	=	1 Megohm	±20%	POSC-11
R-31	=	220 kilohms	±10%	REC-20BF
R-32	=	220 kilohms	±10%	REC-20BF
R-33	=	25 kilohms	±.05%	510-390
R-34	=	7.5 kilohms	± 2%	314-411
R-35	=	25 kilohms	±.05%	510-390
R-36	=	1.875 kilohms	± 1%	510-369
R-37	=	400 Ohms	±10%	REPO-4
R-38	=	22 kilohms	±10%	REC-20BF
R-39	=	5 kilohms	± 5%	REPO-1031
R-40	=	33 kilohms	±10%	REC-20BF
R-41	=	33 kilohms	±10%	REC-20BF
R-42	=	82 kilohms	±10%	REC-20BF
R-43	=	6.8 kilohms	±10%	REC-20BF
R-44				
R-45	=	120 kilohms	±10%	REC-20BF
R-46	=	250 kilohms	±10%	POSC-11
R-47	=	820 kilohms	±10%	REC-20BF
R-48	=	220 kilohms	±10%	REC-20BF
R-49	=	100 Ohms	±10%	REC-20BF
R-50	=	1 Megohm	±10%	REC-20BF

*To be adjusted in lab due to variation of R-14

CAPACITORS

C-1	=	0.022 μf	±20%	COW-25
C-2	=	0.001 μf	±10%	COM-20B
C-3	=	0.022 μf	±20%	COW-25
C-4	=	0.001 μf	±10%	COM-20B
C-5	=	0.1 μf	±10%	COW-25
C-6	=	0.005 μf	± 1%	COM-30E
C-7	=	0.001 μf	± 1%	COM-30E
C-8	=	0.005 μf	± 1%	COM-30E
C-9	=	0.01 μf	± 1%	COM-30E
C-10	=	0.005 μf	± 1%	COM-30E
C-11	=	0.001 μf	± 1%	COM-30E
C-12	=	0.005 μf	± 1%	COM-30E
C-13	=	0.001 μf	± 1%	COM-30E
C-14	=	5 μμf	±20%	COM-20B
C-15	=	5 μμf	±20%	COM-20B
C-16	=	11 μμf	per section	846-400
C-17	=	100 μμf	per section	368-411
C-18	=	0.01 μf	±10%	COW-25
C-19	=	20 μf	450 DCWV	
C-20	=	20 μf	450 DCWV	
C-21	=	20 μf	450 DCWV	COEB-25
C-22	=	20 μf	450 DCWV	
C-23	=	20 μf	450 DCWV	COE-5
C-24	=	0.01 μf	±10%	COM-35B
C-25	=	0.01 μf	±10%	COM-35B
C-26	=	0.0022 μf	±10%	COL-71
C-27	=	50 μf	15 DCWV	COE-47
C-28	=	0.013 μf	± 1% (AERO-#1445)	CM-45E 1604-40
C-29	=	0.013 μf	± 1% (AERO-#1445)	CM-45E 1604-40
C-30	=	0.013 μf	± 1% (AERO-#1445)	CM-45E 1604-40
C-31	=	0.013 μf	± 1% (AERO-#1445)	CM-45E 1604-40

MISCELLANEOUS

T-1	=	Transformer	485-439-2
T-2	=	Transformer	578-403
S-1	=	4 Position Switch	SWRW-60-2
S-2	=	DPST Switch Part of S-1	
S-3	=	SPST Switch	SWT-323
S-4	=	2 Position	SWRW-61
F-1, F-2	=	Fuse 0.5 amp 3AG SLO-BLO 115V	FUF-1
F-1, F-2	=	Fuse 0.3 amp 3AG SLO-BLO 230V	FUF-1
J-1	=	Jack	CDSJ-820
PL-1	=	Input Plug	CDPP-562A

A.T. Numbers Used; 1,2,3,4, 7,8,9,10,11

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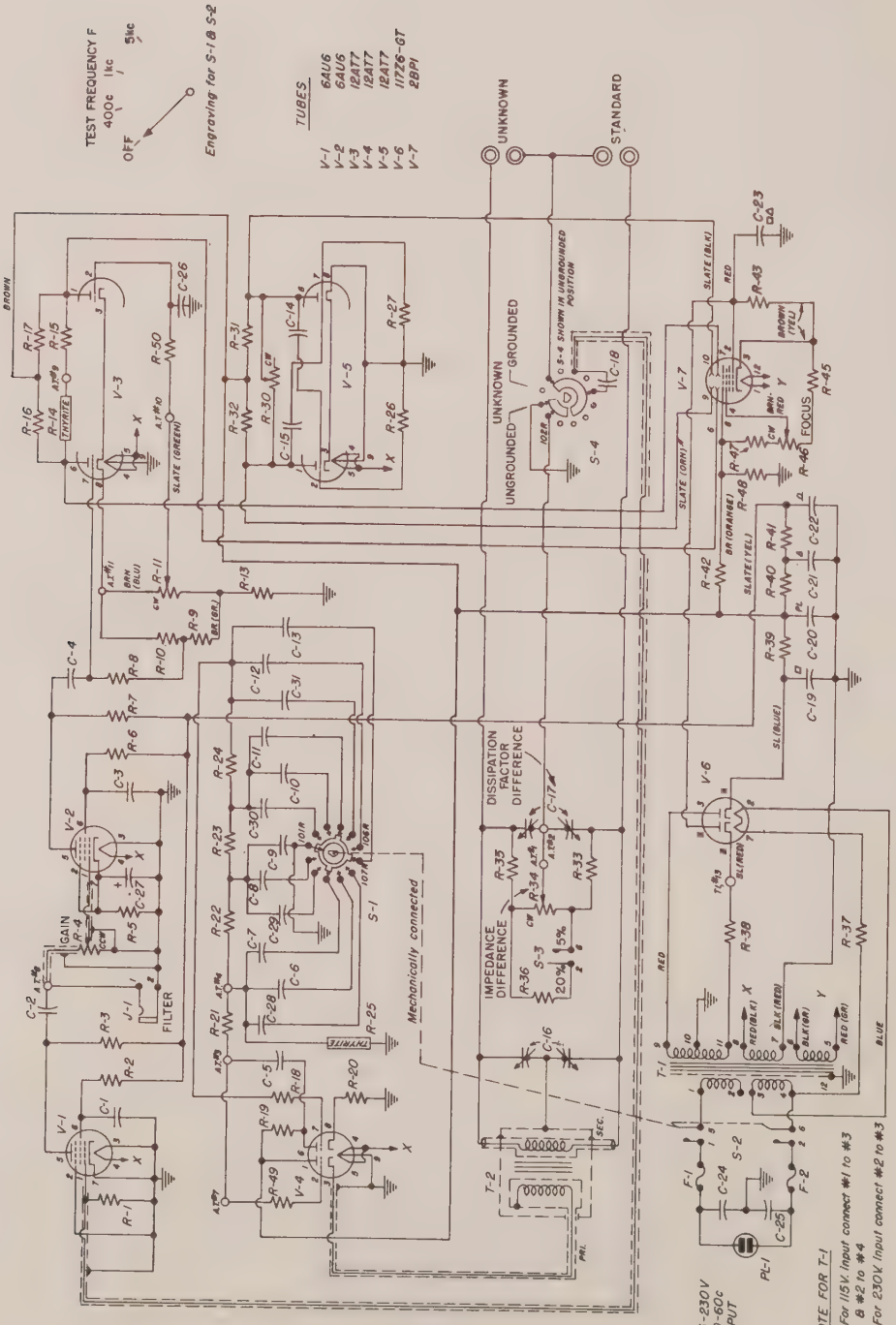

Wiring Diagram for the Type 1604-B Comparison Bridge

MP MASTER
MA33827